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THIRD INTERIM DEVELOPMENT REPORT

Capacitors, High KVA Transmitting Types, Glass Dielectric

1 July - 30 September, 1953

Contract No. NObsr-57558

Corning Glass Works Corning, N. Y.

RESTRICTED

INTERIM DEVELOPMENT REPORT

for

CAPACITORS, HIGH KVA TRANSMITTING TYPES,

GLASS DIELECTRIC

This report covers the period July 1 to September 30, 1953

CORNING GLASS WORKS
CORNING, NEW YORK

Navy Department Bureau of Ships Electronics Division

Contract NObsr-57558 June 23, 1952

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ABSTRACT

This report contains a summary of the work during the three months ending September 30, 1953 on the development of design and manufacturing techniques of high KVA types of transmitting capacitors, and is the third quarterly report under this contract --NObsr-57358. Results of measurements of equilibrium temperature under radiofrequency operation of samples prepared in specified ways are presented and discussed. The effect on performance of the nature of the electrical connections and of the potting wax is shown. The dependence of hot spots at the surface of the capacitor on the internal arrangement of the components is discussed and the effect of this on the inferred power factor of the capacitor is shown. An outline of the proposed program for the next three months period is appended.

CAPACITORS, HIGH KVA TRANSMITTING TYPES, GLASS DIELECTRIC

PURPOSE

The purpose of this program is the development of design and manufacturing techniques for transmitting types of capacitors, case sizes 75 through 95, with glass as the dielectric material. The external design of these capacitors will be kept as close as possible to existing forms, so that they will be physically interchangeable with mica capacitors; and the electrical design will be determined so that wherever possible they meet the test and operating requirements outlined for these capacitors. Straight-line production facilities will be set up from which a quantity of each type, to be produced by these methods, will be supplied to the Bureau of Ships for engineering evaluation. The goals of this research, and the requirements on it, are set forth in the Specification Ships-C-595, 14 April, 1952, which defines the aims and purposes of this contract. Portions of this Specification are included with the First Quarterly report, covering work from January 1 to 31 March, 1953.

GENERAL FACTUAL DATA

Personnel

The following members of the Laboratory have spent the designated amount of time on this contract during this reporting period:

Brown, D. N., Research Chemical Engineer	160 hrs.
Fabian, O. [illegible]., Junior Research Physicist	323 hrs.
Sackinger, J. P., Research Physicist	245 hrs.
Sprague, L. G., Research Electrical Engineer	264 hrs.
Carlton, Mrs. K., Research Assistant	74 hrs.
Connor, Mrs. E., Junior Research Assistant	119 hrs.
Engler, Miss B., Junior Research Assistant	119 hrs.
Uncapher, Mrs. L., Junior Research Assistant	42 hrs.
Arnold, Mrs. M., Laboratory Assistant	146 hrs.
Gee, G. [illegible]., Laboratory Assistant	2[illegible]3 hrs.
Smith, Dr. G. P., Senior Research Associate	93 hrs.

DETAILED FACTUAL DATA

I. Case and mounting of the capacitors.

Development work during this period has been confined mainly to consideration of and measurements on the 75 size, which is the smallest of the seven sizes to be produced. Some design has been done on the larger sizes, and all work has been planned so that the information gained on one size will be usable for other sizes. In order to make this information as common to all sizes as possible, we have decided that, except possibly for the very lowest capacitances, all the component stacks will be of the conventional types, with all dielectrics in parallel within the stack, rather than the shielded foil construction in which the arrangement is a series-parallel one. These all-parallel components are adaptable to stacking by automatic or semi-automatic methods. The completed capacitor is then formed of as many components in series as are necessary to meet the test or radio-frequency operating voltages, and as many in parallel as are necessary to meet the required capacitance. For mechanical reasons this assembly is included within a suitable container, which will in every instance be interchangeable with its mica capacitor counterpart. The wall of the container is a right cylinder of glass tubing, which for the 75 size is approximately 2.5" O.D. and 2¼" long, with .1" wall. The end plates are 1/8" brass with specified peripheral dimensions. A band near the

ends of the glass cylinder may be metallized and the brass plates soldered thereto. This seal has been made in experimental capacitors by means of a synthetic rubber base, two component, industrial sealing compound (Minnesota Mining and Manufacturing Co. EC801). Preliminary tests show that this adhesive remains fairly flexible at $-55^{\circ}C$ and stable up to perhaps $150^{\circ}C$. Compared to a solder joint, an adhesive joint seems to have the advantages of economy and ease of fabrication. The use of such material will be investigated further through vibration and thermal cycling.

II. Electrical design of the capacitors.

Nominal values of capacitance chosen for initial work in case size 75 are 1000, 10,000 and 100,000 mmfd. The specified radiofrequency power at 1 megacycle is a maximum in the region of 1000 mmfd. For capacitances greater than 10,000 mmfd, the specified radiofrequency power is markedly reduced -- the specified radiofrequency currents increase very little with capacitance above this value. Approximately 350 volts at radiofrequencies has been taken to be the point of onset of corona for these component stacks with .0027" thick dielectric, and about 700 volts, 60 cycles AC, as a safe life test rating for the same thickness of glass. These values are derived from earlier reports and cited references. At low capacitances, therefore, the expected voltage of corona onset determines the design, and at higher capacitances,

the life test requirements are the controlling criteria. For different frequencies this breakover occurs at different capacitances; the above two capacitances are within this region. Table I shows the construction resulting from these considerations.

Table I

Capacitance		RF Voltage .3mc	1.mc	Peak working Voltage	Components in Series	Total Stack Capacitance
100	mmfd	4840	3180	6000	14	19,600
1000	"	2720	1200	6000	8	64,000
10000	"	920	320	4000	5	250,000
100000	"	135	35	1000	2	400,000

Figure I displays the results on a CY75, nominally 1000 mmfd, for the equilibrium temperature of an arbitrary spot on the surface of the cylinder versus circulating power. The particular wax used, a low power factor microcrystalline type of wax, began to melt in the region of 75°C -- about 50°C temperature rise. The inferred power factor for less than this temperature rise, derived from equilibrium measurements on a similar container with a resistor enclosed, is .25%. The peculiar shape of the curve, and the relatively large fluctuations indicated in the equilibrium value for some of the points, are probably the result of the wax within the capacitor melting, allowing thermal currents to form. The results on another sample are shown as serial number two, with a derived power factor of .11%. These power factors are

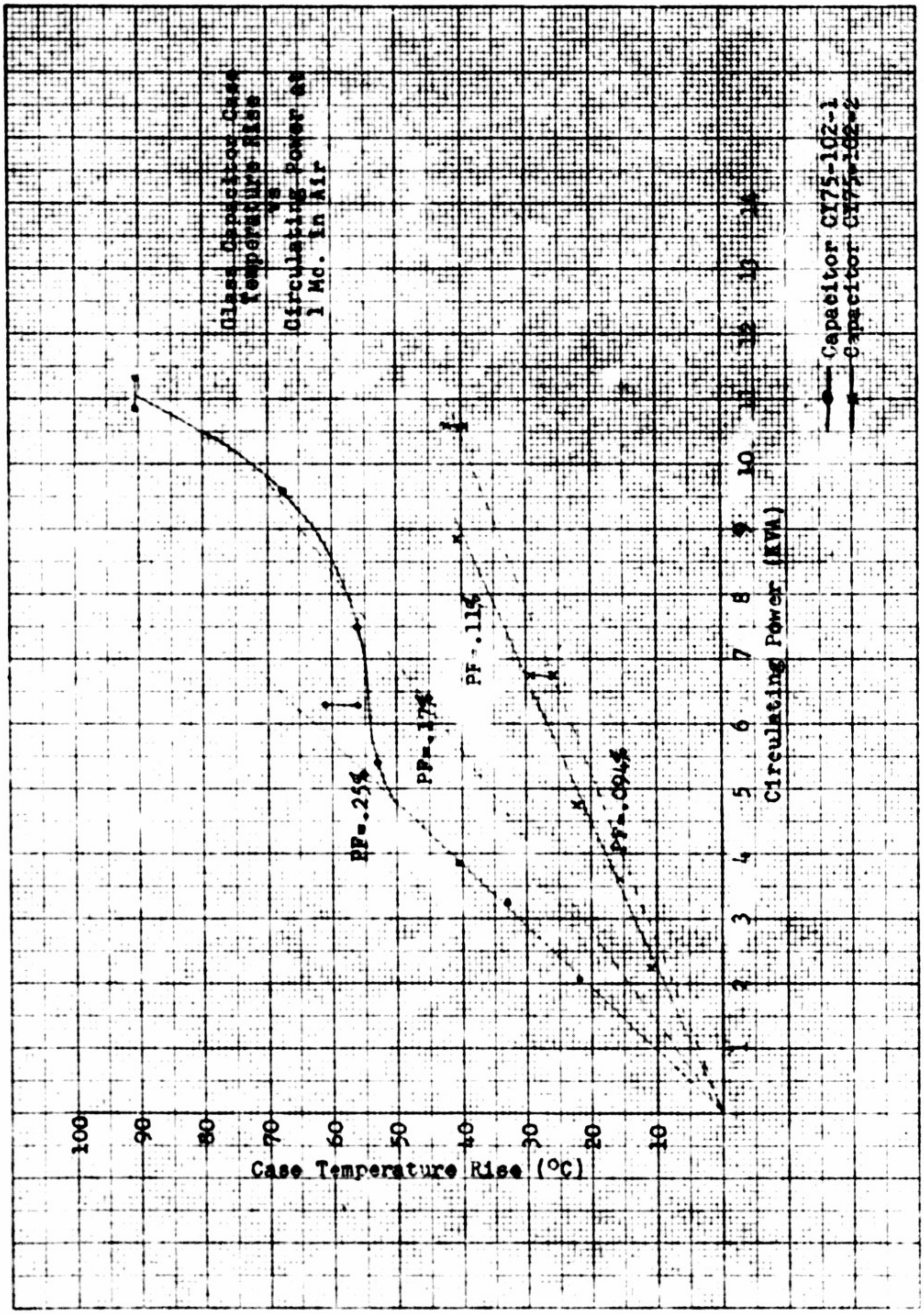

Glass Capacitor Case Temperature Rise vs Circulating Power at 1 Mc. in Air
Capacitor CI75-102-1
Capacitor CI75-102-2
PF=.25%
PF=.17%
PF .11%
PF=.094%
Circulating Power (KVA)
Case Temperature Rise (°C)
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10

FIGURE 1

much higher than expected. Dismantling one of these samples and replacing the terminal straps with heavier material did not significantly affect these results. It was suspected that a relatively large resistance existed at the series connections betweeh the stacks. A special tool had been designed to fold a heavy aluminum or other metal clip around the exposed foils of the capacitor stacks, and to crimp them together. It was considered possible that the potting wax, whose function in this design is primarily mechanical, had entered these crimped joints and increased their resistance. Several joints were made and their resistance measured by a Kelvin double bridge method. Results are shown in Table II, for resistances of these joints in ohms.

Table II

No.	Type Joint	Resistance Before Waxing	Resistance After Waxing
A	Al foil to Cu - crimped	1900×10^{-6}	3250×10^{-6}
B	Al foil to Cu - crimped	1710×10^{-6}	3620×10^{-6}
C	Al foil to Cu - spot-welded	440×10^{-6}	440×10^{-6}
D	Al foil to Cu - " "	370×10^{-6}	370×10^{-6}
E	Al foil to Al - crimped	3320×10^{-6}	12200×10^{-6}

It is seen that there was no change in the resistance before and after waxing for spot-welded joints, but that there was a large change for crimped joints. To determine the number of average-sized spots necessary, the measurements detailed in Table III were made.

Table III

Sample No.	No. of Welds (per 1-1/4")	Resistance (micro-ohms) Measured	Average
1	3	565	
2	3	567	
3	3	527	553
4	6	479	
5	6	510	
6	6	520	503
7	9	469	
8	9	480	
9	9	530	493
10	12	510	
11	12	470	
12	12	470	483

Above 6 spot-welds, or about 5 per inch, the decrease in resistance is very small, and may be neglected compared to the total of the resistance elements in the capacitor. Figure 2 shows the behavior at 1 megacycle of two separate 1000 mmfd 75 size capacitors with welded joints. The derived power factors are .090% and .072%. These results are collected in Table IV, with the circulating power at 1 megacycle to give 15°C temperature rise in air.

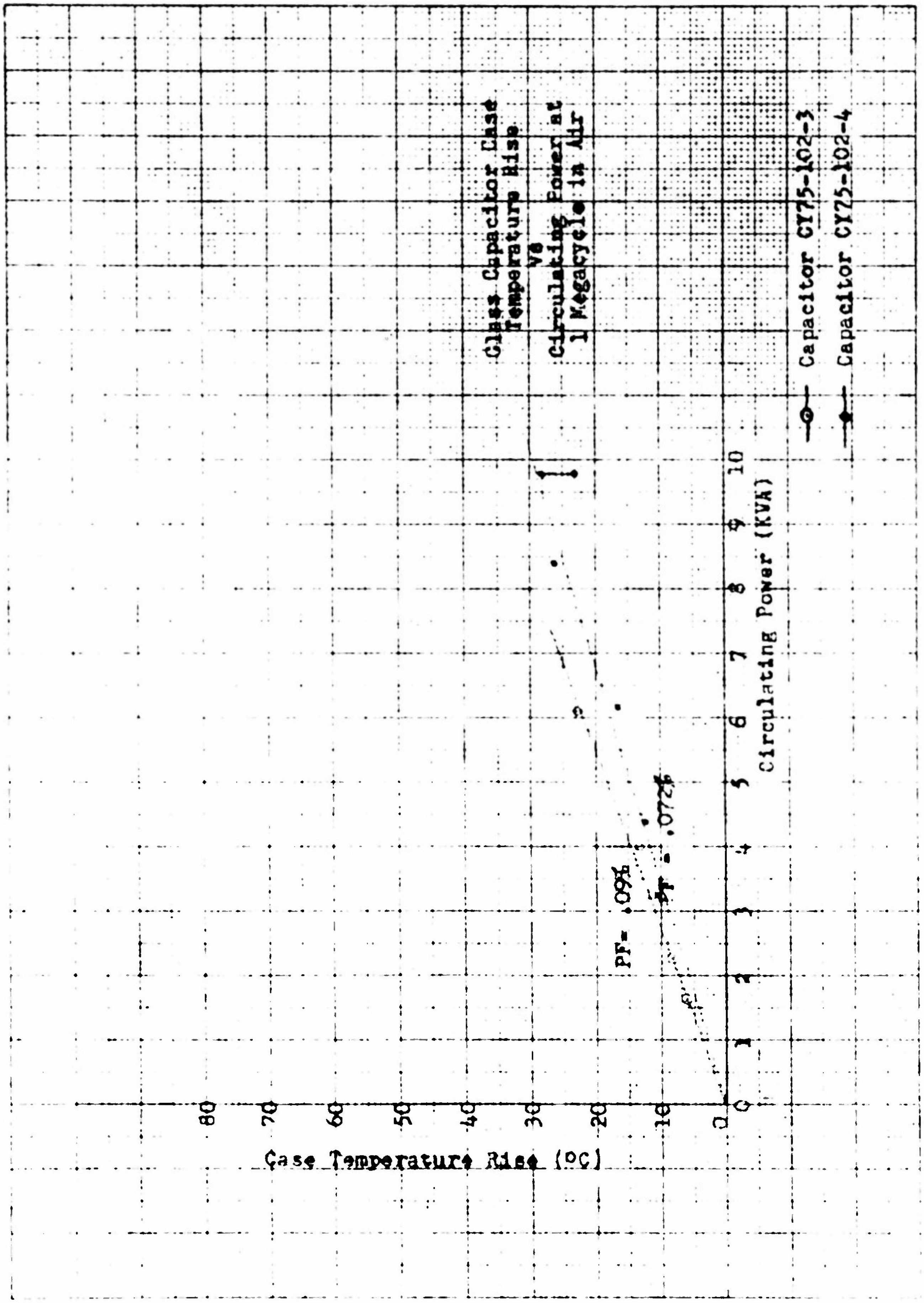

Glass Capacitor Case
Temperature Rise
Vs
Circulating Power at
1 Megacycle in Air
Capacitor CY75-102-3
Capacitor CY75-102-4
Circulating Power (KVA)
Case Temperature Rise (°C)
0 1 2 3 4 5 6 7 8 9 10
0 10 20 30 40 50 60 70 80

FIGURE 2

Table IV

Capacitor No.	Measured Capacity (mmf)	PF at 1 Kc. (%)	PF at 1 Mc. in Air (%)	PF at 1 Mc. in Oil (%)	Circulating Power at 1 Mc in Air for 15°C case Temp. Rise (KVA)
CY75-102-1	1182	.115	.25-.17		1.45-2.1
CY75-102-2	1190	.095	.11-.094		3.4 -3.9
CY75-102-3	1069	.07	.09	.077	4.1
CY75-102-4	1036	.07	.072		5.1

It is seen that even for the lowest power factor so far achieved the circulating power at 1 megacycle for 15°C rise is about 5 KVA. This is to be compared to 9 KVA implied by the rated current of 7.5 amperes at this frequency. To meet this requirement, the power factor will have to be reduced to approximately .040%.

In the glass capacitor stacks the electrodes, which are .00025" or .00017" thick aluminum foils, are sealed to the glass and of course make good thermal contact. These foils extend out from the capacitor stack edges, and are near and in some instances touching the inside surface of the glass cylinder, whose wall thickness is only .1". Therefore any energy generated within the dielectric is very quickly removed to the walls of the container. For a given surface temperature it follows that the dielectric temperature is certainly lower than for a capacitor potted in a conventional thick-walled ceramic housing. Also at equilibrium, variations in temperature over the surface of the glass will be greater. To find the magnitude of this effect, a capacitor

case was filled with some capacitor stacks of about the same size and geometry as in an actual capacitor, and these were wound with a resistance wire. After sealing this was then immersed in an oil bath, and the temperature rise of the circulating oil was measured in terms of watts dissipated. The capacitor designated as number 3, which had power factor .090% inferred from the rise in temperature of a particular spot on the case in air, was then immersed in this same bath. Figure 4 shows results of this determination based on the slope of the straight line of Figure 3. The slope of the straight line best fitting these points is .077%. This represents more nearly an average temperature rise for the test capacitor.

The construction of the capacitor will require, we believe, some kind of a mechanical support for the capacitor stacks within the case. A wax or resin will be most suitable -- because the case can be sealed we need impose no moisture sealing requirement on the wax. We need only require that it have sufficiently high melting point and be sufficiently plastic at low temperature. In addition, because we cannot completely avoid inter-stack and other stray capacitances, it should have a reasonably low power factor, and reasonably high resistivity. Dielectric constants of usable materials will all be about the same, so that this latter is a secondary consideration. Several waxes are being tried for their suitability in the light of the above criteria--most of them appear to be reasonably satisfactory.

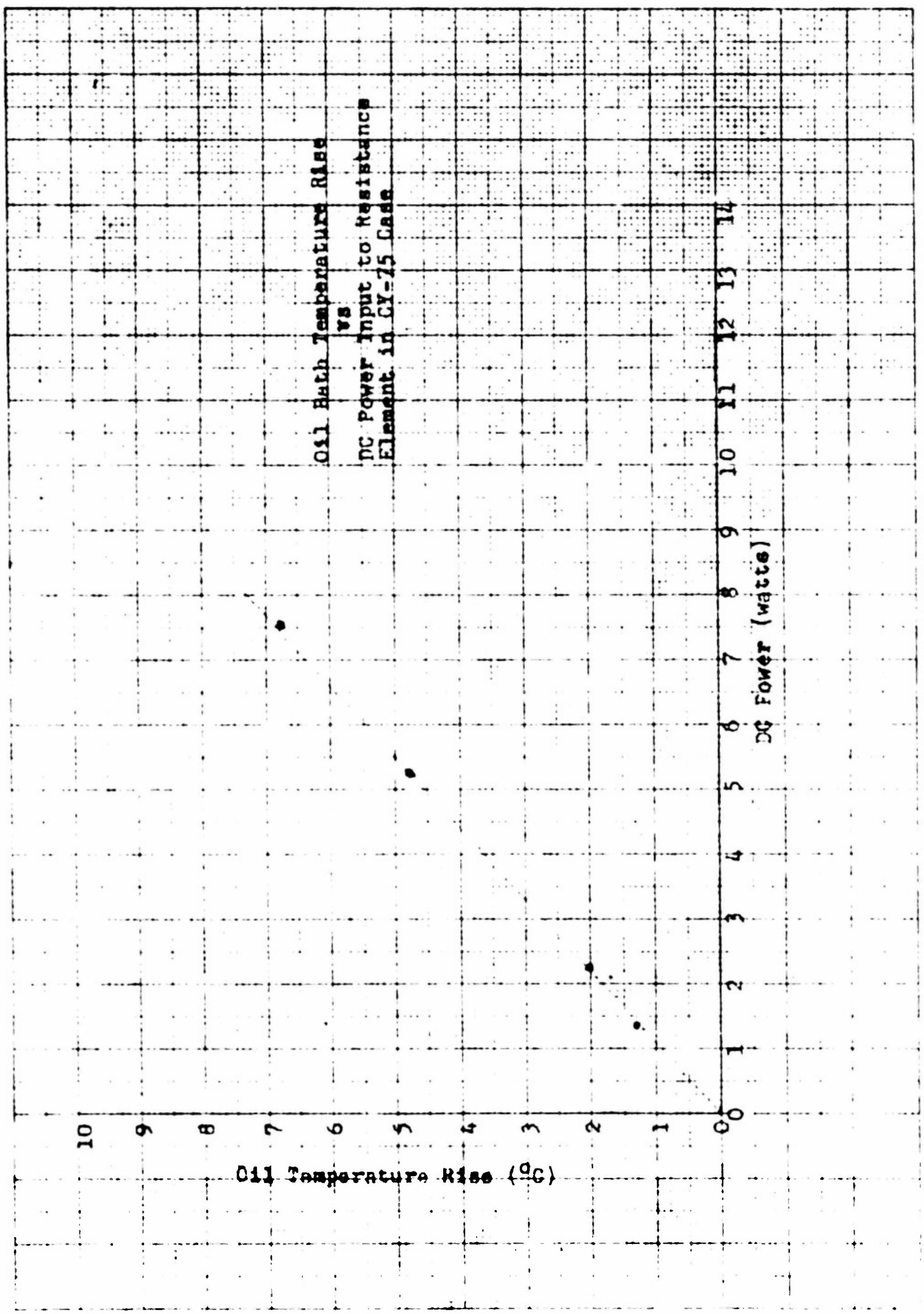

Oil Bath Temperature Rise
vs
DC Power Input to Resistance
Element in CY-75 Case
DC Power (watts)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Oil Temperature Rise (°C)
0 1 2 3 4 5 6 7 8 9 10

FIGURE 3

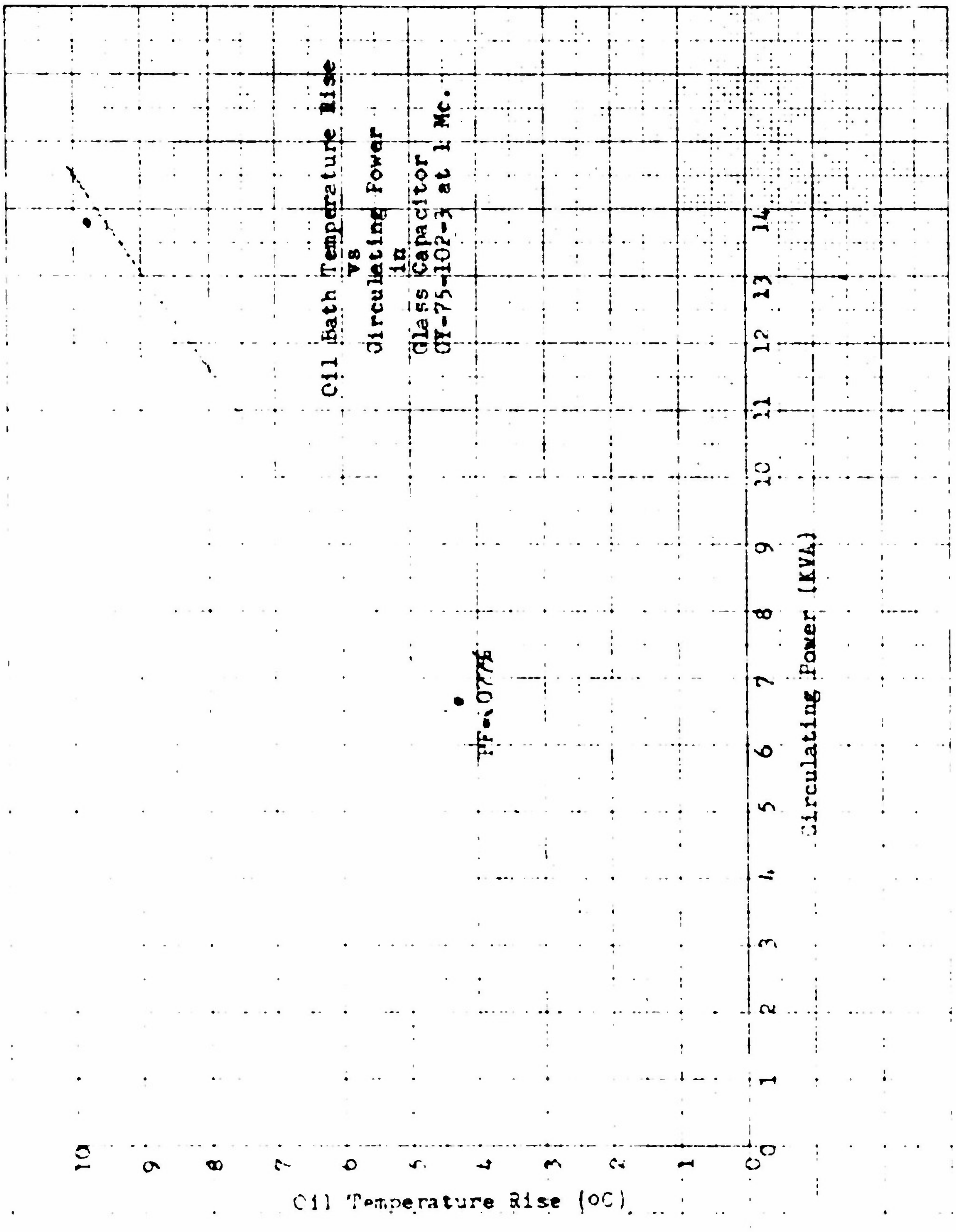

Oil Bath Temperature Rise
vs
Circulating Power
in
Glass Capacitor
GY-75-102-3 at 1 Mc.
PF=.0775
Oil Temperature Rise (oC)
Circulating Power (KVA)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

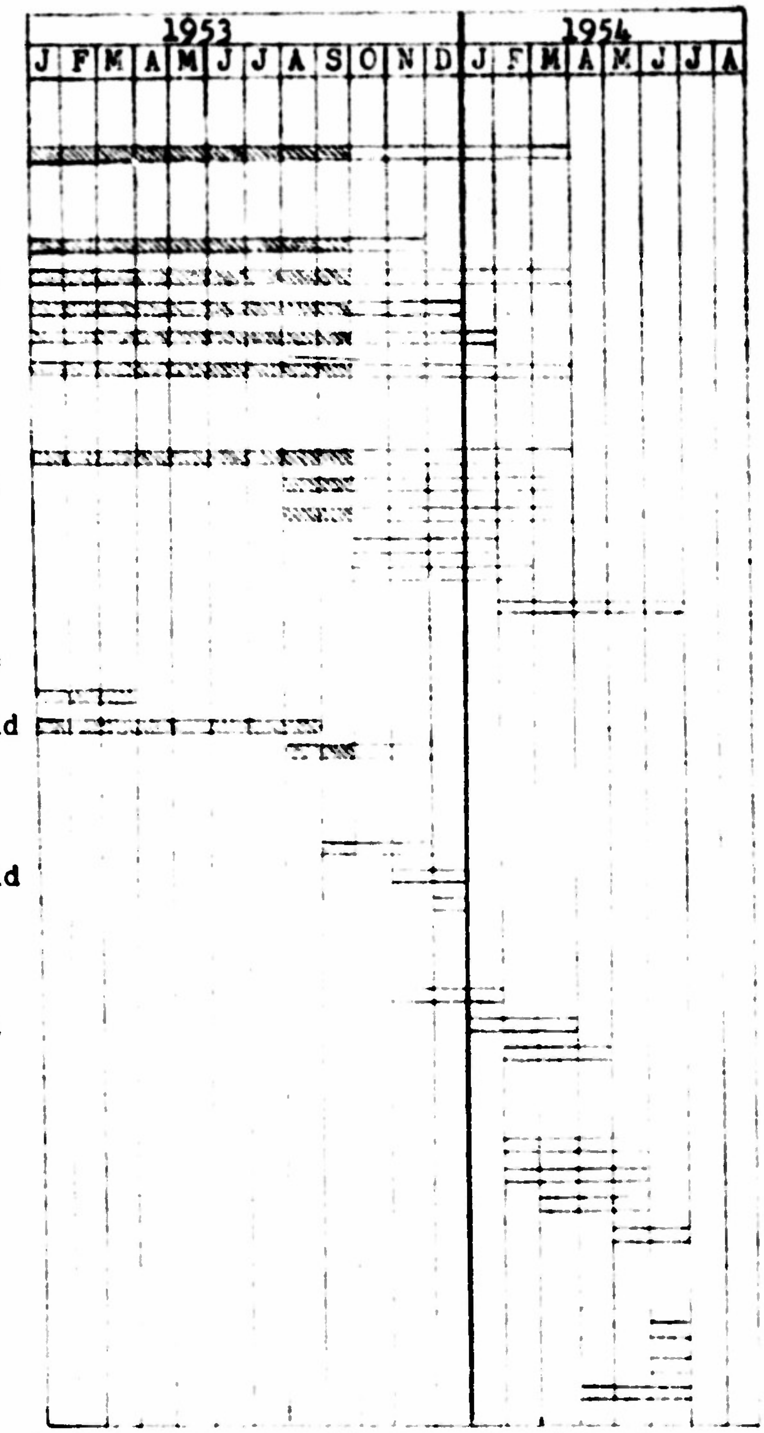
FIGURE [illegible]

CORNING GLASS WORKS

PROJECT PERFORMANCE AND SCHEDULE

Contract NObsr-57558 September, 1953

1. Background, correlation with concurrent research
2. Component (stack) design
   - Design and development
   - Dielectric strength test
   - Corona voltage tests
   - Radiofrequency tests
   - Life tests
3. Capacitor design
   - Design and development
   - Dielectric strength test
   - Radiofrequency tests
   - Vibration tests
   - Moisture tests
   - Life tests
4. Radiofrequency oscillator*
   - Design
   - Obtain material and build
   - Test
5. Life test equipment*
   - Design
   - Obtain material and build
   - Test
6. Production facilities
   - Layout
   - Obtain & build equipment
   - Complete facilities
7. Production of capacitors
   - Components
   - Capacitors
   - Performance tests
   - Delivery
8. Other engineering
   - Final report
   - Microfilm
   - Patent disclosures



*Necessary for performance tests, but to be supplied by Corning Glass Works.

FIGURE 5

PROGRAM FOR NEXT INTERVAL

The program of work for the next interval is diagrammatically presented in the Project Performance and Schedule, Figure 5. The evaluation of the performance of specified capacitances in various case sizes will be continued. The general design will be that of unit components in a series-parallel array within a container of standard size. Work on reduction of hot spots on the surface of the container will continue, perhaps by creation of an artifical isothermal surface. An analysis of the interrelation of the required components for the various capacitances and case sizes will continue, so that their number can be reduced to a minimum. Additional investigations will be necessary to find the optimum potting wax and case adhesives.